Anatomy & Physiology of the Kidney

Anatomy of the Kidney

General Description

- **Shape:** Bean-shaped
- **Size: 11 × 6 × 3 cm**
- **Weight: 120–170 g** in adults
- **Coverings:**
  - Fibrous capsule
  - Perirenal fat
  - Renal fascia (also encloses suprarenal gland)

Parts of the Kidney

- **Hilum:**
  - Medial
  - Contains renal vein, renal artery, lymphatics, renal pelvis
- **Renal pelvis:**
  - Divides into **2–4** major calyces → minor calyces
- **Parenchyma:**
  - Cortex: **~1 cm** thick, granular, forms columns of Bertini
  - Medulla:
    - **8–18** pyramids
    - Conical, striated
    - Apex forms papillae projecting into minor calyces
- **Medullary rays:**
  - Striated elements radiating through cortex

Surface Anatomy & Relations

Position

- Retroperitoneal
- Opposite **T12–L3**
- Right kidney lower than left (liver effect)

Morris's Rectangle

- **Horizontal lines:** T11 and L3
- **Vertical lines: 2.5 cm** and **7.5 cm** from midline
- Hilum opposite **L1, 5 cm** from midline

- ✧ **Posterior Relations**
  - ◈ **Bones: 11th–12th ribs**
  - ◈ **Muscles:** Diaphragm, psoas major, quadratus lumborum, transversus abdominis
  - ◈ **Nerves:** Subcostal, iliohypogastric, ilioinguinal
  - ◈ **Vessels:** Subcostal artery

Blood Supply & Innervation

- ✧ **Arterial Supply**
  - ◈ Renal arteries from aorta at **L1–L2**
  - ◈ Branches:
    - ↳ Interlobar → arcuate → interlobular arteries
    - ↳ Afferent arteriole → glomerulus
- ✧ **Venous Drainage**
  - ◈ Parallels arterial pattern
- ✧ **Lymphatics & Nerves**
  - ◈ Lymphatics accompany vessels
  - ◈ Sympathetic & parasympathetic fibers from celiac plexus

Nephron

- ✧ **Definition**
  - ◈ Renal corpuscle + tubule draining into collecting duct
- ✧ **Types**
  - ◈ **Superficial & midcortical:**
    - ↳ Short loops of Henle
  - ◈ **Juxtamedullary:**
    - ↳ Long loops reaching inner medulla
- ✧ **Tubular Components**
  - ◈ Proximal convoluted tubule
  - ◈ Loop of Henle
  - ◈ Distal convoluted tubule
  - ◈ Collecting duct

Renal Corpuscle

- ✧ **Components**
  - ◈ **Bowman's capsule:**
    - ↳ Parietal layer: flat epithelial cells
    - ↳ Visceral layer: podocytes
    - ↳ Urinary space in between
  - ◈ **Glomerulus:**
    - ↳ Capillary tuft from afferent arteriole
    - ↳ Drains into efferent arteriole

- ✧ **Glomerular Filtration Barrier**
  - ◈ Endothelial fenestrae
  - ◈ Glomerular basement membrane (type IV collagen, negative charge)
  - ◈ Podocyte foot processes with slit pores
- ✧ **Mesangium**
  - ◈ Location: between capillary loops
  - ◈ Functions:
    - ↳ Structural support
    - ↳ Phagocytosis
    - ↳ Contractile regulation of filtration surface

Efferent Arterioles

- ◈ Cortical glomeruli → peritubular capillaries
- ◈ Juxtamedullary glomeruli → vasa recta
- ◈ **Vasa recta:** Hairpin loops - Maintain medullary hypertonicity

Juxtaglomerular Apparatus

- ✧ **Components**
  - ◈ **Macula densa:** senses NaCl in DCT
  - ◈ **Epithelioid cells:** renin secretion
  - ◈ **Lacis cells**
  - ◈ **Peripolar cells**

Renal Functions

- ✧ **Excretory**
  - ◈ Waste elimination
  - ◈ Water & electrolyte balance
- ✧ **Acid–Base Regulation**
  - ◈ H^+ excretion
  - ◈ Bicarbonate reabsorption or loss
- ✧ **Blood Pressure Control**
  - ◈ Renin–angiotensin system
- ✧ **Hemopoietic**
  - ◈ **Erythropoietin:**
    - ↳ **90%** from renal cortex
    - ↳ Stimulus: tissue hypoxia
- ✧ **Endocrine**

Renin – Prostaglandins - Active vitamin D - Kallikrein–bradykinin - Erythropoietin

Renal Hemodynamics & Filtration

- ✧ **Renal Blood Flow**
  - ◈ **20–25%** of cardiac output
- ✧ **Glomerular Filtration**
  - ◈ Ultrafiltrate: **90–120 mL/min**
  - ◈ **130–180 L/day**
  - ◈ Net filtration pressure: **~10 mmHg**

- ✧ **Autoregulation**
  - ◈ Myogenic reflex
  - ◈ Tubuloglomerular feedback

Tubular Function

- ✧ **Proximal Convoluted Tubule**
  - ◈ Reabsorbs **65–80%** of Na^+, water, Cl^-
  - ◈ Active glucose, amino acid, HCO_3^- reabsorption
- ✧ **Loop of Henle**
  - ◈ Thick ascending limb:
    - ↳ Reabsorbs **25%** of filtered Na^+
    - ↳ Impermeable to water
  - ◈ Countercurrent multiplier
  - ◈ Medullary tonicity up to **1400 mOsm/L**
- ✧ **Distal Nephron**
  - ◈ DCT:
    - ↳ NaCl & Ca^{2+} reabsorption
    - ↳ Water impermeable
  - ◈ Collecting duct:
    - ↳ Aldosterone: Na^+ reabsorption, K^+/H^+ secretion
    - ↳ ADH: water reabsorption

Urine Formation

- ✧ **Volume & Osmolality**
  - ◈ Volume: **~1.5 L/day** (**0.4–20 L/day**)
  - ◈ Osmolality: **30–1400 mOsm/L**
  - ◈ Minimum UOP: **400 mL/day**

Assessment of Kidney Disease

- ✧ **Laboratory**
  - ◈ Urinalysis
  - ◈ Renal function tests
- ✧ **Immunological**
  - ◈ Complement, autoantibodies, CIC
- ✧ **Pathology**
  - ◈ Renal biopsy (LM, IF, EM)
- ✧ **Radiology**
  - ◈ US, Doppler, CT, IVU, angiography
  - ◈ Radionuclide scans (DMSA, DTPA)